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ABSTRACT

Engineering mechanics is recognized as one of the core subject matter areas of most engineering and technology educational programs. The study of mechanics and particularly the applications of problem solving to rigid bodies at rest (statics) has proven to be troublesome to students. Systematic problem solving includes analysis, synthesis, and calculations. There is evidence to indicate that students gain broader insights into analysis and synthesis when freed from detailed computational method. The computerized model relieves the students of the mechanics of calculation and checks the students' analysis and synthesis of a broad range of statics problems on an individualized basis. The function and structure of the model is discussed. Two populations of students were used in testing the model. One group consisted of eight sophomore engineering students, who had completed a computer programming course. The second group consisted of 27 freshman technology students who had not completed a computer programming course. The overall attitudes of both groups were positive toward the model on the pretest. Engineering students became more positive on the posttest. Technology students became significantly negative on the posttest. It was suggested that technology students probably would have gained more from the model if they also had had to turn in problems. (LS)

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THE DEVELOPMENT OF A COMPUTERIZED MODEL FOR TEACHING ENGINEERING STATICS

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THE PROBLEM

Systematic problem-solving is frequently encountered by technical students and includes analysis, synthesis, and calculations as shown in Table 1. Although this definition is appropriate for problem-solving courses in general, it is particularly appropriate for engineering mechanics which is recognized as one of the core subject matter areas of most engineering and technology educational programs. The study of mechanics and particularly the application of problem-solving to rigid bodies at rest (statics) has proven to be extremely troublesome to students. The principal reason is the free-body diagram.

TABLE 1

PROBLEM-SOLVING

ANALYSIS	The separation of a substantial whole into constituents for individual study.	REASONING PROCESS, or SETTING-UP THE PROBLEM
SYNTHESIS	The combining of the separate elements to form a coherent whole.	
CALCULATIONS	Slide rule Hand calculator Computer	VERY REPETITIVE AND MANY TIMES VERY TIME-CONSUMING

According to Figure 1, there is only one way to arrive at a correct solution to a problem, but there are approximately twenty ways to arrive at an incorrect solution. If a student arrives at an incorrect solution, how does he know where to start checking for his error?

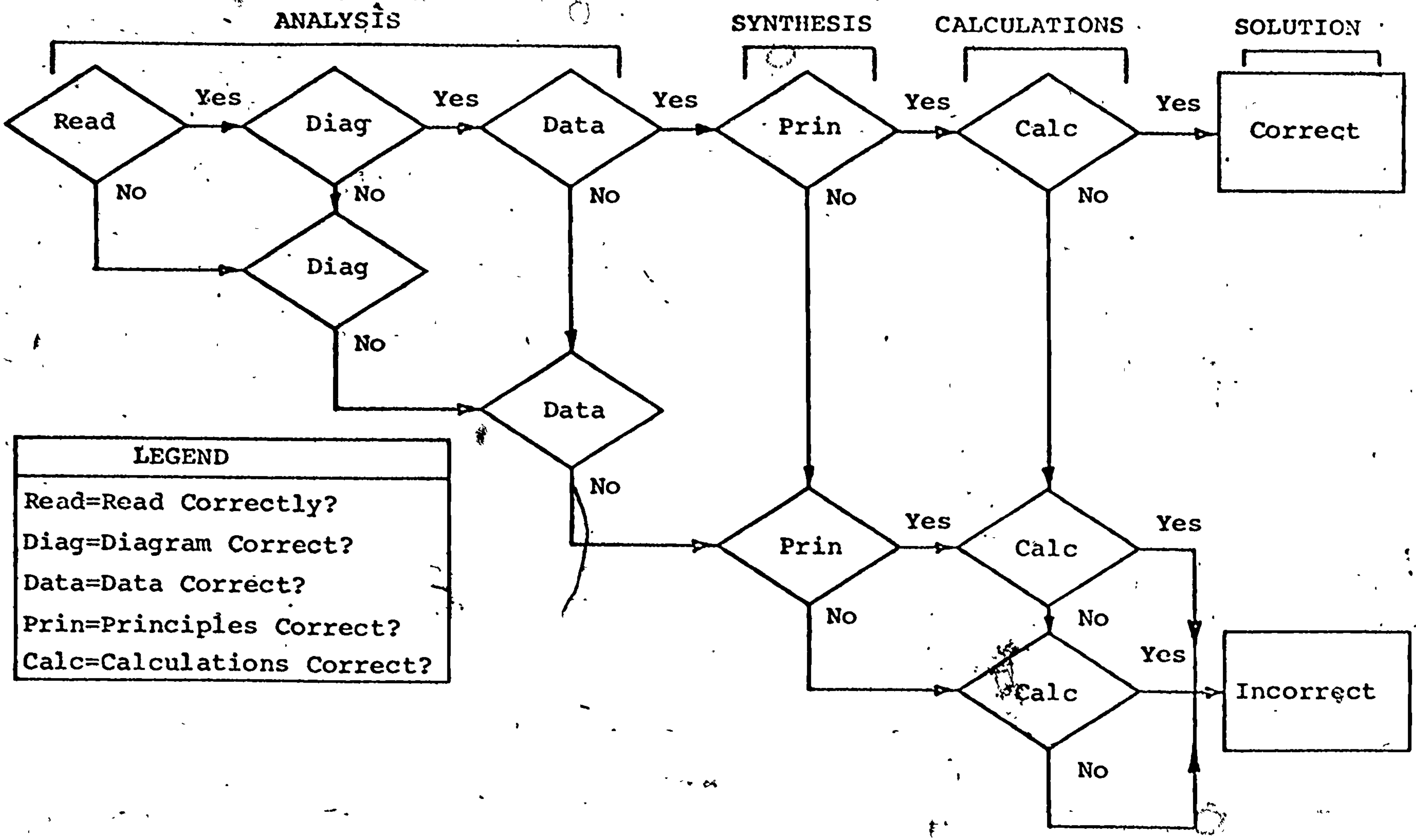


Figure 1. Flowchart of the Solution to a Problem

There is evidence to indicate that students gain broader insights into analysis and synthesis when freed from detailed computational methods. Therefore, the computerized model was developed to relieve the students of the mechanics of calculation and to check the student's analysis and synthesis of a broad range of statics problems on an individualized basis.

ASSUMPTIONS MADE WHEN DEVELOPING THE MODEL

1. Most students are more interested in cranking out an answer than in developing their ability to reason properly.
2. The analysis and synthesis are the most important parts of problem-solving.
3. Many of the errors in problem-solving occur during the analysis of the problem.
4. Given enough time, most students can make accurate calculations.

PRINCIPAL REASONS FOR DEVELOPING THE MODEL

1. Help students become more systematic and efficient in their reasoning.
2. Force the student to check the analysis and synthesis when an answer is incorrect rather than check the calculations.

THE MODEL

Why use the computer?

The computer should be used to perform tasks which cannot be accomplished as quickly, accurately, efficiently, and thoroughly by any other means.

Function of the model

The model checks the student's analysis and synthesis of a wide variety of statics problems with individualized feedback. Faculty input is minimal, and the output is a hard copy in a neat and systematic form.

The model is transportable

1. Written in Basic Fortran IV.
2. Requires only 16K of core if a means is available to overlay subroutines.
3. Any standard statics textbook may be used.
4. Can be used with or without vector algebra.
5. Can be used by students with no previous experience with a keypunch or computer.
6. Free choice of location of axes in most problems.

Structure of the model

The model consists of a deck of cards given to the students plus a series of subroutines on the disk. The deck of cards includes all control cards needed; all necessary common, dimension, equivalence, read, and format statements for the main program; and all data cards required for the read statements.

The students are also given all of the required call statements for the subroutines and the read and format cards for reading the chapter and problem numbers. A user's manual is also given to each student.

Types of problems which can be used

1. Problems which require only one free-body diagram.
2. Two- and three-dimensional problems.
3. Problems which do not have friction at impending motion.
4. Problems which have only forces and/or moments as unknowns.
5. Problems which have a maximum of six known forces plus known moments.

Debugging the model

The model is easy to debug.

1. Each time a subroutine is called, the name is printed.
2. Each time data is read, it is immediately written out for checking.
3. At the conclusion of each subroutine which performs calculations, the results of the calculations are written out.
4. If a problem is prematurely terminated, the student can check the printout to see just where the error occurred.

Individualized feedback

When using the model, the students are given the problems and the answers. The individualized feedback is given in the form of diagnostics. It was not the intent of the design of the model to tell a student exactly where an error occurred, but to give enough information so the student would know what to check in the analysis and synthesis.

Initial data capture

It was imperative that the data be tabulated in as simple and systematic form as possible. Table 2 is a summary of all the data, and Table 3 is the sheet given to the student for tabulation of the data.

Card for the keypunch drum

Each student was given a card for the keypunch drum which tabulated to the desired column by striking the skip key. Punching of data cards was thus greatly simplified.

The model checks the following:

1. Number of active forces.
2. Number of active moments.
3. Number of reactive forces.
4. Number of reactive moments.
5. Equations of equilibrium used.
6. If the information for distributed loads is incorrect.
7. If the system was in equilibrium with no reactive forces and moments.
8. Linearly dependent equations.
9. Zero matrix.
10. More equations than unknowns.

TABLE 2

SUMMARY OF DATA

FORCES: CONCENTRATED

NAME	NO	F1	F2	F3	F4	F5	F6	F7		
	1	$\lvert\bar{F}\rvert$	l	m	n	x	y	z		
	2	$\lvert\bar{F}\rvert$	x_1	y_1	z_1	x_2	y_2	z_2		
	3	$\lvert\bar{F}\rvert$	x_s	y_s	z_s	x	y	z		
	4	$\lvert\bar{F}\rvert$	F_x	F_y	F_z	x	y	z		
	5	$\lvert\bar{F}\rvert$	α	l	m	x	y			
	6		F_x	F_y	F_z	x	y	z		

PTLINE:

NAME	NO	F1	F2	F3	F4	F5	F6	F7		
	1		l	m	n	x	y	z		
	2		x_1	y_1	z_1	x_2	y_2	z_2		
	3					x	y	z		

COUPLE:

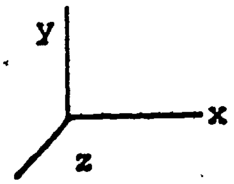
NAME	NO	F1	F2	F3	F4	F5	F6	F7		
	1	$\lvert\bar{C}\rvert$	l	m	n					
	2		C_x	C_y	C_z					

DLOAD:

NAME	NO	A	B	C	D	E	G	R	R1	R2

FOR DLOAD ONLY:

NO=1



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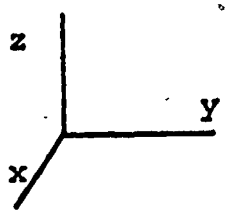


TABLE 3

TABULATION OF DATA

NAME	NO	F1	F2	F3	F4	F5	F6	F7		
		A	B	C	D	E	G	R	R1	R2

1 45 89 1617 2425 3233 4041 4849 5657 6465 7273 80

DECIMAL POINT

11. More unknowns than equations. (Gives some variables in terms of free variables.)
12. Equations of the form 35.2=0.
13. If the number of known forces and moments is greater than six.

If the problem was solved with no error messages but the answer was incorrect, the student had to check how he entered data for forces and moments. (Back to the analysis.)

Faculty input

Faculty members are required to enter the following seven pieces of information for each problem assigned: chapter number, problem number, number of active forces, number of active moments, number of reactive forces, number of reactive moments, and the type of force system. Table 4 shows the instructions for faculty members.

How to use the model

A person using the model is required to read a problem, draw a free-body diagram showing all external forces and moments acting on the body, name all forces and moments, show a rectangular coordinate system on the free-body diagram which designates the location of the origin and the direction of the axes, give a point for each force which the force passes through, take the data from the free-body diagram necessary to arrive at a solution to the problem, and finally tabulate the data in suitable form to be punched on computer cards. When the data cards are punched, the main program and the data deck are entered in the deck

TABLE 4

FOR FACULTY MEMBERS ONLY

HOW TO ENTER ANSWERS:

Answers are stored in Array KM(5,7) for five problems as follows:

ARRAY KM(5,7)

Chapter Number	Problem Number	F_a	M_a	F_r	M_r	Type System

F_a=Number of active forces

M_a=Number of active moments

F_r=Number of reactive forces

M_r=Number of reactive moments

Type System:

1. Coplanar-concurrent
2. Concurrent-three-dimensional
3. Coplanar
4. Parallel-three-dimensional
5. Coplanar-parallel
6. Three-dimensional

These answers are entered in subroutines FILKME, FILKMC, and FILKMM. Each time a new set of five problems is used, 35 computer cards must be punched, and the subroutine put back on the disk.

given the student for submission to the computer center. Examples are shown at the end of the paper.

Computers used with the model

The model has been tested on an IBM 360-22 computer, a CDC 6500 computer, and a CDC 6600 computer.

Testing of the model

Two populations of students were used in testing the model. One consisted of eight sophomore engineering students, enrolled in an engineering statics class, who had completed a computer course in Fortran IV programming. The second consisted of twenty-seven freshmen technology students, enrolled in a technology statics class, who had not completed a course in Fortran IV programming.

Students' attitudes toward the model were measured by administering a pre-test and a post-test to both populations. The overall attitudes of both engineering and technology students were positive toward the model on the pre-test. Engineering students became more positive on the post-test, but the change was not significant. Technology students became negative toward the model on the post-test, and the change was significant. Significant differences were measured at the .05 level of significance.

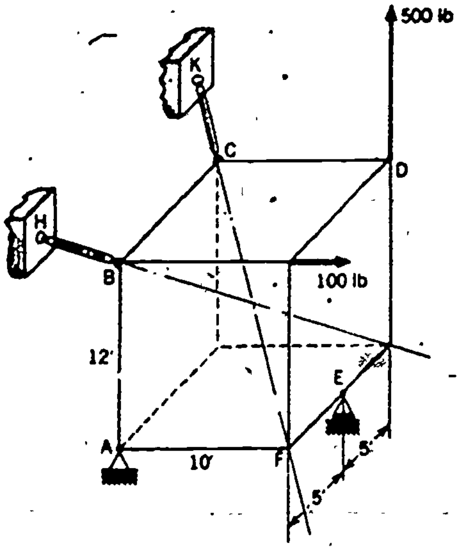
On the post-test, engineering and technology students agreed that: little keypunching was required; no previous experience with a keypunch was necessary to effectively use the model, previous experience with a computer was necessary or at least desirable, and the model did not interfere with the learning of statics.

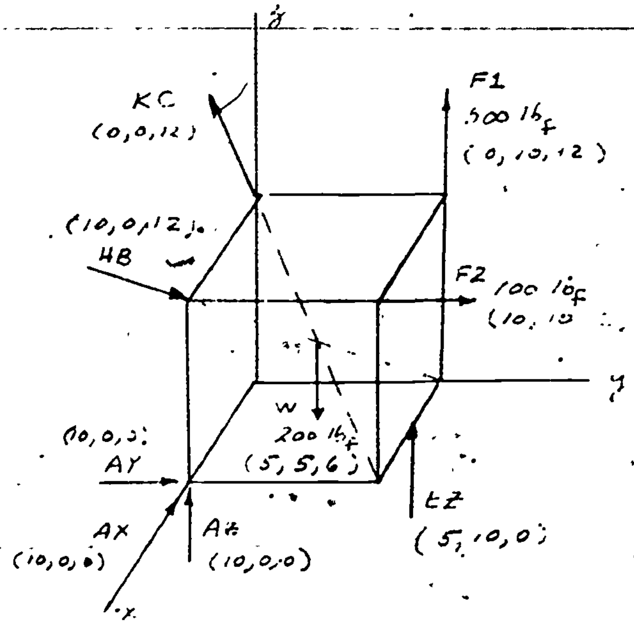
The engineering students experienced little difficulty using the model, considered the diagnostics to be valuable, found the program easy to debug, considered the model a good teaching tool, considered the model a valuable asset to learning, and considered the model an effective means of helping them to become more systematic in problem-solving.

The technology students did not agree with the engineering students on any of these items.

When the experiment ended, both faculty members who taught the technology class emphasized that they were certain their students would have gained much more from the model if they had been required to turn in all problems assigned as was required of the engineering students.

In Fig. 5.100 is shown a block of material weighing 200 lb. It is supported by members KC and HB, whose weight we neglect, a socket joint support at A, and a smooth frictionless support at E. Members KC and HB have directions collinear with diagonals of the block as shown. What are the supporting forces for this block?

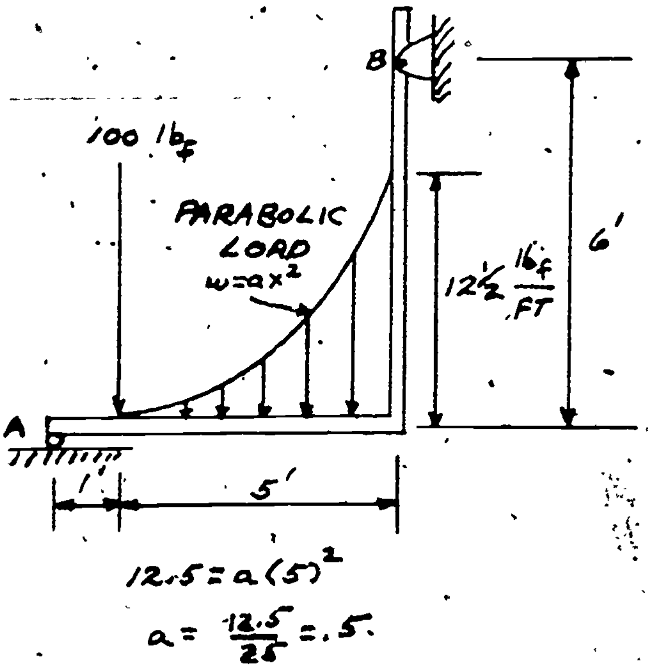


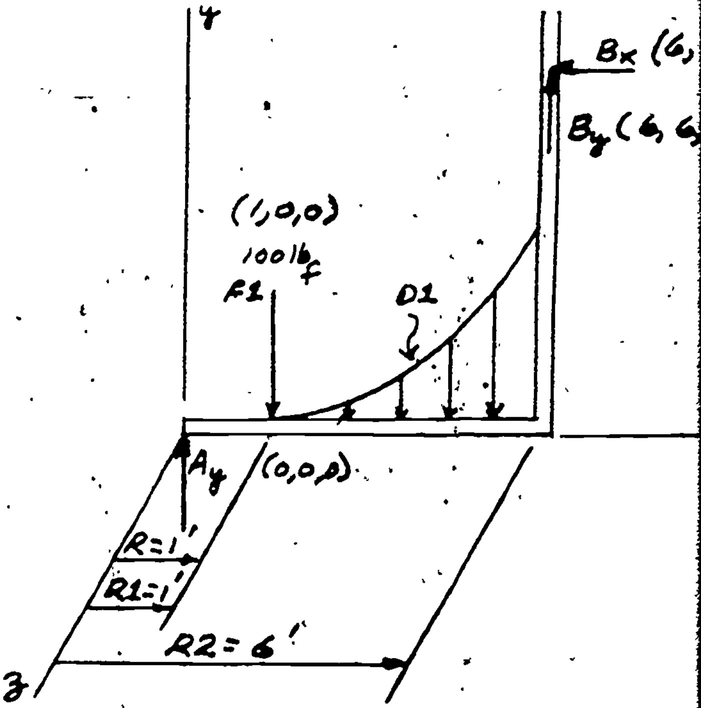


TABULATION OF DATA

NAME	NO	F1	F2	F3	F4	F5	F6	F7		
		A	B	C	D	E	G	R	R1	R2
W	6				-200.	5.	5.	6.		
F1	6				500.		-10.	12.		
F2	6			100.		10	10.	12.		
KC	3	1.	-10.	-10.	12.			12.		
HB	3	1.	-10.	10.	-12.	10.		12.		
AX	6		-1.			10.				
AY	6			1.		10.				
AZ	6				1.	10.				
EZ	6				1.	5.	10.			
P1	3									

Calculate the reactive forces at A and B.

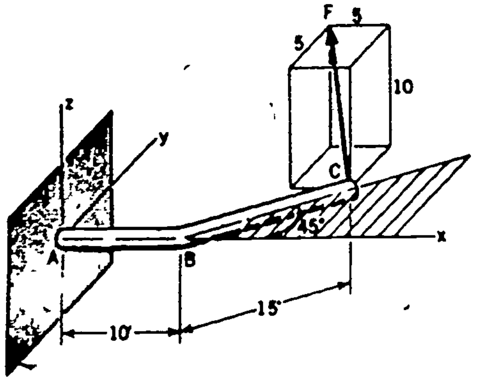


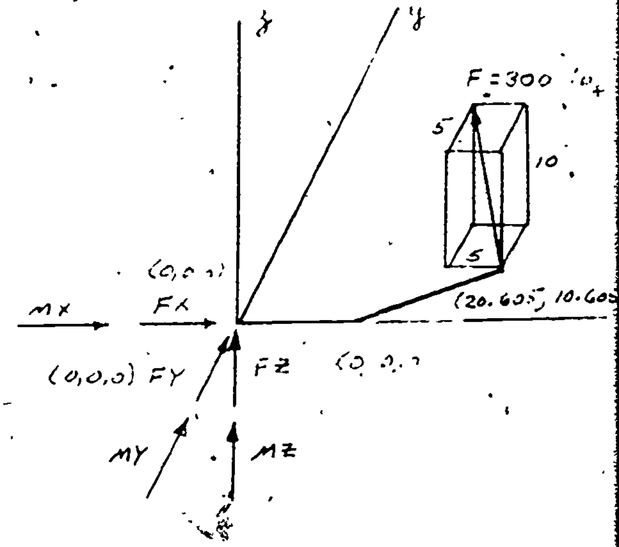


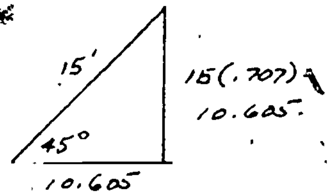
TABULATION OF DATA

NAME	NO	F1	F2	F3	F4	F5	F6	F7		
		A	B	C	D	E	G	R	R1	R2
F1	6			-100.		1.				
D1	1	.5						1.	1.	6.
P1	3									
AY	6			1.						
Bx	6		-1.							
BY	6			1.						

Calculate the reactive force and moment at point A for a value of $F=300\ lb_f$.







TABULATION OF DATA

NAME	NO	F1	F2	F3	F4	F5	F6	F7		
		A	B	C	D	E	G	R	R1	R2
F	3	300.	-5.	5.	10.	20.605	10.605			
P1	3									
FX	6		1.							
FY	6			1.						
FZ	6				1.					
MX	2		1.							
MY	2			1.						
MZ	2				1.					